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HIGH-VORTICITY STRUCTURES IN AXISYMMETRIC SWIRLING FLOWS

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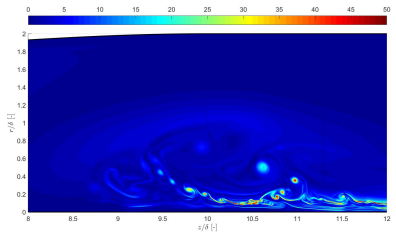
This paper studies the vortical structures and their dynamics found in an inviscid axisymmetric open-ended pipe flow undergoing vortex breakdown. The vortical structures are studied by means of a transient numerical simulation of a sudden step increase from a swirl number prior to breakdown to a swirl number above breakdown. A grid study reveals the necessity for a very high spatial and temporal resolution to resolve the finest flow structures. After the step response of the flow to the sudden swirl increase has died out, the flow undergoes breakdown and an axisymmetric bubble appears near the central axis. In the immediate wake of this bubble, a shear layer of high vorticity is formed. The maximum vorticity found in this shear layer grows exponentially in time to a value which is more than 100 times higher than the initial value. Further growth is prevented by the roll-up of the unstable shear layer into vortices which are convected upstream by the recirculation zone of the vortex breakdown bubble. During this convection, these vortices undergo complex dynamics, such as pairing and stretching. Arriving at the upstream stagnation point of the breakdown bubble, this feedback mechanism of vortical convection creates a highly anisotropic transient flow field in the bubble and its wake.



Vorticity magnitude to show the vortical structures in the breakdown bubble.